A HISTORICAL ANALYSIS OF U. S. AIR FORCE TACTICAL AIRCREW ERROR IN OPERATIONS DESERT SHIELD/STORM

A thesis presented to the faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

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This thesis identifies and analyzes tactical aircrew error in the Gulf War and determines various mission effectiveness implications of the errors. From analysis of critical incidents collected from over 400 aircrew members, the study identifies error types, and categorizes them as frequent, common, or infrequent errors. Additionally, the study identifies the percentage of errors associated with the three aspects of mission effectiveness, namely, impact on the combat mission, safety implications, and training implications. The analysis identifies twenty-seven distinct error types. Frequent errors are defined as occurring in over 25 percent of the incidents. They include: (1) Decision making errors, (2) situational awareness errors, (3) procedural errors, and (4) crew coordination errors, in that order of frequency of occurrence. Common errors occurred in greater than 10 percent of the incidents and include: (1) communications errors, (2) pressing too far, (3) regulatory deviation, (4) flight lead errors, and (5) weather related errors. Fifty-two percent of the errors had safety implications, 24 percent had training implications, and 13.6 percent impacted on the mission. Nine and one-half percent could not be reliably classified into any of the three areas.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (Reference to this study should include the foregoing statement.)

ABSTRACT

A HISTORICAL ANALYSIS OF U.S. AIR FORCE TACTICAL AIRCREW ERROR IN OPERATIONS DESERT SHIELD/STORM by MAJ Anthony T. Kern, USAF, 84 pages,

This thesis identifies and analyzes tactical aircrew error in the Gulf War and determines various mission effectiveness implications of the errors. From analysis of critical incidents collected from over 400 aircrew members, the study identifies error types, and categorizes them as frequent, common, or infrequent errors. Additionally, the study identifies the percentage of errors associated with the three aspects of mission effectiveness, namely, impact on the combat mission, safety implications, and training implications.

The analysis identifies twenty-seven distinct error types. Frequent errors are defined as occurring in over 25 percent of the incidents. They include: (1) Decision making errors, (2) situational awareness errors, (3) procedural errors, and (4) crew coordination errors, in that order of frequency of occurrence. Common errors occurred in greater than 10 percent of the incidents and include (1) communications errors, (2) pressing too far, (3) regulatory deviation, (4) flight lead errors, and (5) weather related errors. Fifty-two percent of the errors had safety implications, 24 percent had training implications, and 13.6 percent impacted on the mission. Nine and one-half percent could not be reliably classified into any of the three areas.

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CHAPTER ONE

INTRODUCTION

Background

The existence of error has been a vexing problem for the military professional since the day man picked up his first club and missed his enemy because of a poorly aimed swing. It is occasionally stated that the study of military history tends to focus on error more than normalcy. Maurice Matloff, Chief Historian at the Army Center of Military History, mentioned the historian's preoccupation with the aberration when he states "he (the historian) is overly concerned with the *pathology* of the human condition . . . rather than its . . . so called normality."[1] Despite this assertion, the study of military error is important if one are to improve his warfighting capabilities. Many of the most influential institutions throughout history began as training organizations dedicated to reducing military error in combat. These include, but are certainly not limited to:

1. Professional military schools such as the United States Army Command and General Staff College (USACGSC),
2. The United States Air Force (USAF) Fighter Weapons School
3. The United States Navy (USN) Top Gun Air Combat School.[2]

In each of these cases, senior military leaders perceived a problem and designed institutions with an eye towards reducing operational or tactical level error in warfighting. In spite of the

multitude of historical data and analysis of error in war, a detailed analysis of *tactical error* by aircrews has not yet been fully studied, especially in DESERT SHIELD/STORM, the Persian Gulf conflict of 1991. There have been several small studies, focused primarily on fratricide incidents, but a comprehensive look at aircrew error is a significant omission, because these errors have implications not only for wars of the future, but how training is accomplished today.

Three reasons may help explain the lack of historical critical analysis of tactical level aircrew error to date. The first is that historians tend to focus on commanders rather than "trench fighters" or individuals. The second reason is that tactical error in light of an overall victory may not be perceived as significant in the historical sense. The third reason is that the political climate of the times, for example, budget cutbacks and roles and missions debates make it unfashionable or politically risky to identify shortcomings within one's own branch of the military. Each will be discussed individually.

While tactical errors were certainly not overlooked by senior officers of the day, they often escape the focus of historians who seem to prefer to write about command level tactical decision making or the operational and strategic level decision making of high-ranking officers. It remains true, however, that in some cases, officers are renowned for their strict punishment of those who do not perform or who make an error at a crucial point. One example is General Curtis LeMay, former Commander in Chief (CINC) of the USAF Strategic Air Command (SAC), who was known as a commander who tolerated <u>no</u> mistakes in his bomber fleet. As a twelve-year veteran of SAC operations, this

researcher was well aware of the unwritten, but often stated unofficial legacy of General LeMay; "To err is human, but to forgive is not SAC policy." While the leadership style of general officers like LeMay has received a great deal of historical analysis, the mistakes made by those unfortunate few (many?) that served underneath these leaders have not. Similarly, tactical aircrew error in the Gulf War has remained largely unstudied, with the notable exception of the highly publicized fratricide cases, which have been studied by accident investigation teams and widely storied in the popular media.

Secondly, in light of the tremendous success of DESERT SHIELD/STORM, many historians and analysts do not feel that tactical aircrew error is historically significant. But much can be learned from a detailed analysis of successes as well as failures. A historical analysis of the success of airpower in the Persian Gulf war shows that USAF aircrews flew nearly 200,000 sorties. During that time they achieved outstanding tactical and operational success by any measure of merit. Total losses of USAF aircraft were only 27; 22 lost in combat and five noncombat losses.[3] It must be kept in mind, however, that these numbers represent errors observable through analysis of *results* only. To obtain a truer picture of the level of error that actually occurred, data must be drawn from those who flew the missions, for not all errors resulted in lost aircraft, and most errors went unreported.

The final reason is that historians have chosen not to analyze tactical level error in light of overall victory, because it is not politically popular during an era of in-fighting about Service roles and missions. In a post-war interview, the Secretary of Defense (SECDEF)

flatly stated that "the air campaign was decisive."[4] Indeed, the word "decisive" is the keystone of argument between the services. Having achieved decisiveness (at least in the mind of the SECDEF) in the Gulf War, why paint a dark side to the USAF's one true and overwhelming victory? DESERT SHIELD/STORM provides historians and airpower analysts with a new and unique opportunity to look into the minds of warriors, specifically aviators, in an attempt to better understand the nature of combat error. From this identification and analysis, training programs can target the problem more precisely. Additionally, an "end state" or desired outcome to aircrew decision making and judgment training can be defined. This opportunity should not be missed.

Historical Overview

The Persian Gulf has long been an area of strategic interest to the United States. Following the Iran-Iraq conflict, an eight-year war which ended in 1988,

> Iraq emerged . . . in possession of the fourth largest military system in the world. Equipped with modern aircraft, armored forces, ballistic missiles, an arsenal of chemical and biological weapons, and a nascent nuclear weapons program, Iraq's military system was a powerful threat to its regional neighbors and, thus, to interests outside the Middle East.[5]

With the fall of the Soviet Union, the U.S. strategy shifted from a concern about Soviet intervention to a strategy of promoting regional stability. The U.S. Central Command (CENTCOM) commander (USCINCCENT) General H. Norman Schwarzkopf was responsible for developing plans for countering regional aggression, should it occur. "In February 1990, USCINCCENT asked the U.S. Army Concepts Analysis Agency to conduct War Game PERSIAN TIGER to test OPLAN

1002-88, the existing blueprint for countering an Iraqi attack by a coalition of Kuwait, Saudi and U.S. forces."[6] After the analysis of PERSIAN TIGER, it was discovered that U.S. forces would arrive far too late to prevent the seizure of Kuwait and parts of Saudi Arabia in the event of a rapid Iraqi armored attack. The CENTCOM planners knew at this time, that if an Iraqi attack occurred, airpower would play a key role because of its inherent speed and global reach.

The plan that was developed for this contingency was USCINCCENT OPLAN 1002-90. If required, it was to be implemented in three phases: (1) Deterrence; (2) Counterair, Interdiction and Defensive Operations; and (3) Counteroffensive.[7] Lieutenant General Charles Horner, Commander of Air Forces, U.S. CENTCOM, briefed General Schwarzkopf, USCINCCENT, in April, 1990 on the air plan to support 1002-90. The United States Air Force Official Air Power Survey, describes the contents of his briefing:

> Phase One (deterrence) emphasizes providing an immediate air defense capability, while building up the overall capabilities needed to fight immediately, if required. The next two phases (delay/attrition and counteroffensive) provided for air attacks on targets like airfields, transportation chokepoints, chemical weapons storage and production sites and delivery means (Scud missiles) and, if the Iraqis did use chemical weapons, key refineries, power plants, and the Baghdad nuclear center.[8]

In July of 1990, Saddam Hussein made a televised speech that heightened the stakes, threatening that he would attack Kuwait if many of his demands were not met. The next day, Kuwaiti forces were put on alert.[9] Several exercises were conducted to prepare forces for possible action, as well as to send a signal of U.S. interest in the region. Exercise IVORY JUSTICE deployed USAF KC-135 tankers to the

region for air refueling training with the United Arab Emirates (UAE) Mirage fighters. Perhaps more importantly, Brigadier General Buster Glosson, the newly appointed Deputy Commander of Joint Task Force Middle East, supervised the exercise to gain valuable experience with his staff and the region. As a part of IVORY JUSTICE, General Glosson established a mobile tactical air control center at Abu Dhabi, the capital of the United Arab Emirates. A second exercise, INTERNAL LOOK, was a command post exercise which simulated coalition responses to an Iraqi invasion into Kuwait and Saudi Arabia. The Gulf War Air Power Survey noted that "exercisers placed great value on the immediate availability of $1 billion worth of USAF equipment already prepositioned in the Gulf area."[10]

Iraq invaded Kuwait on 2 August 1990 with over 300 tanks and 100,000 troops. The same day, President Bush issued executive orders 12722 and 12723, declaring a National Emergency--an initial step towards mobilizing forces.[11] Within a week, the U.S. was invited into the Kingdom of Saudi Arabia, OPLAN 1002-90 was activated, and U.S. airpower, (in the form of F-15s from Langley AFB and C-141s) was on the move for the middle east. By the end of August, the USAF had F-15s, F-16s, F-15Es, F-4Gs, RF-4Cs, F-111s, F-117s, A-10s, E-3s, RC-135s, KC-135s, KC-10s, and C-130s in theater. C-141s and C-5s flew around-the-clock missions, bringing in troops and supplies. Special Operations helicopters and AC-130 gunships arrived by mid-September.[12] Figure 1 shows the USAF aircraft build up, by both the number and types of aircraft deployed.

On 13 September, General Glosson told General Colin Powell, the Chairman, Joint Chiefs of Staff (CJCS), that the Air Force would be ready to execute its plan "within 24 hours."[13] They continued to train until 17 January 1991 when, at 3 a.m. Baghdad time, the coalition air forces launched DESERT STORM. The fighting continued until 28 February, when "at the direction of the President, offensive air operations cease[d] at 0500Z."[14]

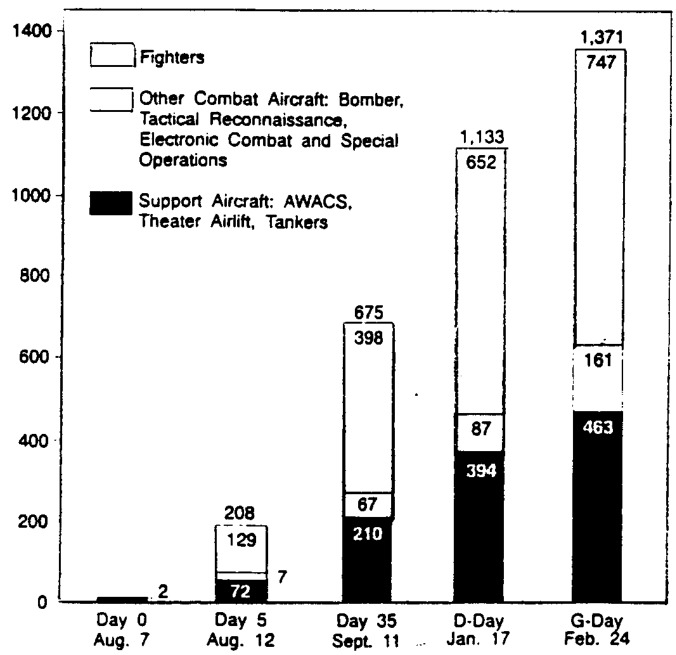

Figure 1. The USAF Aircraft Build up.[15]

In the 43 days of the air war, allied air forces flew an average sortie rate of 3,500 sorties a day. This resulted in 110,000 attack sorties flown by fighter aircraft, 1,624 B-52 missions, 46,000 airlift missions, and over 15,000 air refueling missions "with an overall aircraft mission capable rate [a determinant of mission

readiness based on maintenance capability] of 93.4 percent."[16] General Horner had the following evaluation:.

> I am extremely pleased with [the] performance of coalition air forces. Never in [the] history of warfare have air forces of so many nations been as effectively integrated. Coalition air forces had a spirit of cooperation that made this possible. Air forces played [the] central role in Operation Desert Storm, neutralizing [the] Iraqi Air Force; destroying integrated air defense system, command and control structure, nuclear, biological, and chemical production capability, and capability of producing long range missiles; and severely attriting Iraqi ground forces. We also stand ready to conduct follow-on operations, as needed.[17]

While it is true that the operation in the Gulf was a tremendous success overall, there remain some specific areas in which tactical airpower can be improved. One such area is human performance, and one method for improving it is the further reduction of aircrew error.

Overview of the Study

This study was a three-phase historical case study accomplished through qualitative analysis of tactical aircrew errors. These errors were compiled in the form of *critical incidents*, or short accounts of significant deviations from standard operating procedures, obtained directly from over 400 aviators who flew in the Gulf War. Through historical analysis, the researcher identified error types and drew implications regarding the consequences of these error types for future operations.

In Phase One, critical incident data was compiled from a previous (and incomplete) study conducted at the USAF Human Systems Center (HSC) at Brooks Air Force Base, Texas. These data were collected for the HSC under a government contract by a private research firm to

assist in studies on aircrew human performance in combat. The incident reports were collected from aircrews within days of their return from the Gulf region. The incidents were handwritten on a critical incident form, and then transcribed by personnel at the HSC. None of the words were altered and the incidents remained in the exact words of the aviators. This added considerable strength to the internal and external criticism applied to these data. They were <u>firsthand accounts, from expert eyewitnesses, in their own words</u>. For the purposes of this study, *expert* is defined as a fully trained aircrew member, capable of recognizing errors in the mission. In addition to the eyewitness account of an expert, the incidents can be traced directly to the actual crewmembers so there can be no doubt as to their authenticity.

In Phase Two, these data were searched to identify large categories of error types. Initially, the researcher used an *etic* coding process. Etic codes are categories or ideas which are found within the literature, to guide the categorization. The initial codes and theories selected will come out of the extensive and comprehensive literature review. After this initial sort, *emic* codes, or codes which emerged from the data analysis and did not fit neatly into pre-existing categories, further defined the nature of the error types. For example, if the researcher spotted a recurring trend of *fear* or *stress* while searching through the data, these would be considered emic codes. Finally, using a qualitative process known as *axial* coding, the researcher homed in on relevant themes in the data to weld the analysis securely to the research questions. Axial coding used codes associated with the research questions to tie findings securely to the problem

statement. In the case of this study, the axial codes *of* combat effectiveness, training, and safety were used. These analytical processes are discussed more thoroughly in Chapter Three and were guided by procedures and techniques advocated by authoritative qualitative researchers, such as Lincoln and Guba.[18] Guidance for the study and analysis of historical data drew upon Barzun and Graff, and Matloff. In Phase Three of the research design, the written findings were written up and submited.

Overview of the Chapters

Chapter One will provide an introduction to the problem and the research design. The chapter will provide relevant background information, research questions, significance of the study, delimitations, limitations, and definitions, and outline the organization of the research project and report. Chapter Two contains the literature review, and overviews the nature of human error from a historical perspective, working from the general topic of human error, to the specificity of tactical aircrew error in combat. Chapter Three outlines the theoretical framework and methodology used to categorize and analyze the data. Chapter Four presents the findings. Chapter Five discusses the implications of the findings and final conclusions from the study. In addition, research questions for future study will be identified.

This study represents an opportunity to identify keys that may unlock the future of high technology warfare. Colonel John Warden III, the Commandant of the United States Air Force (USAF) Air Command and

Staff College (ACSC) and principal Air Force planner of the air war in DESERT SHIELD/STORM has made the bold assertion that

> We have moved through the age of the horse and the sail through the age of the battleship and the tank to the age of the airplane [as the primary instrument of waging war]. Like its illustrious ancestors, the airplane will have its day in the sun and then it too will be replaced.[19]

Warden's assertions may or may not come to pass, and their merits will not be debated here. However, in light of the success of DESERT SHIELD/STORM, airpower is certain to be one of the first options considered by the national command authority in future crises.

Thesis Purpose

The purpose of this thesis is to identify specific types of human factors error made by Air Force aviators in OPERATION DESERT SHIELD/STORM. Going beyond mere identification, these errors will be categorized by how they impacted the safety, mission effectiveness, or training during the USAF operational combat missions in which they occurred. Training does occur during combat missions, even though they are not flown for that purpose. These error types will be analyzed and utilized to provide human factors-related feedback to military aviators for the purpose of performance improvement. Historically, human factors studies have been directed almost exclusively towards <u>improving safety</u>. This study proposes a broader, historical look at aircrew error to encompass the impacts of human error on <u>mission effectiveness</u>, which encompasses <u>combat effectiveness</u> (i.e., air to air kill ratios, bombing accuracy) and <u>training effectiveness</u>, which occurs even in combat environments (some would argue especially in combat environments). Improvements in these areas may be much more demonstrable than the

traditional "this crash may have been avoided if--" approach, which is often impossible, or at least extremely difficult to assess through quantitative analysis.

A new Air Force Instruction (AFI 36-2243 Cockpit/Crew Resource Management[CRM]) now requires specific areas of human factors training to be conducted in a career-spanning training system for all Air Force aviators. This study will compare the categories of error uncovered in this historical analysis against the common core curriculum elements within the USAF training systems to access the scope and coverage of the new Air Force guidance.

To summarize, this thesis serves two purposes. First, it will add to the historical picture of USAF aircrew operations in the Gulf War, which has to date been oriented primarily on the successful aspects of USAF operations. Although this study does not intend to diminish the successes associated with this conflict, it does wish to add to the historical picture by viewing the USAF operation from another perspective. Secondly, the data consolidated and analyzed in this study will serve as source materials for curriculum development efforts. It will help to define and refine the objectives and end state goals of current and future human factors training programs.

Thesis Question

What were the mission effectiveness implications of common error types committed by United States Air Force (USAF) aviators in DESERT SHIELD/STORM?

Supporting Research Questions

The following subordinate questions help identify specific types of aircrew error which were associated with lost mission effectiveness. Mission effectiveness, for the purpose of this study, is defined as the completion of objectives, such as targets destroyed, and the accomplishment of available training, in an efficient manner. On a more discreet level, mission effectiveness can be broken down into subcomponents of combat effectiveness, safety, and training effectiveness. Simply stated, an effective mission is one in which an aircrew accomplishes all mission objectives, does so safely, and learns something in the process. Additional research questions address these components.

1. What were the common error types committed by USAF aircrews in DESERT SHIELD/STORM?

2. What percentage of these errors affected combat effectiveness?

3. What percentage of these errors affected safety?

4. What percentage of these errors affected training effectiveness?

Additionally, these error types will be compared to the basic elements in current USAF CRM training to make recommendations to curriculum developers. To that end a fifth research question could be stated as follows:

5. What are the training and curriculum development implications of these errors?

These research questions should provide valuable insights leading to a more complete understanding of aircrew error in DESERT SHIELD/STORM and may have implications for future operations.

Significance of the Study

This study will focus current human factors training and feedback systems as well as broaden the historical picture of the USAF performance in the Gulf War. Researchers have categorized error types within commercial aviation and in other generalized areas of aviation (maintenance, air traffic control, etc.), but never conducted a comprehensive investigation of *military* error types. Such data is essential to military curriculum developers as they seek to refine their human factors training programs by making them more relevant to the combat environment. Decision making under stress has long been an area of study for aviation psychologists and operators alike. The majority of this historical research has been done in the civilian arena, based on the availability of research grants. But military aviation shares much in common with its civilian counterpart, and both should benefit from this study of military aircrew error.

Human factors analysis geared towards an understanding of aircrew error has evolved gradually over the past twenty-five years and is now at the forefront of aviation training and research. Training in this area has become the focal point for addressing concerns on aircrew performance. All areas that relate to aircrew interaction and human error are primarily addressed under the name of Cockpit or Crew Resource Management, CRM for short. Human error in the cockpit holds implications for mission effectiveness, safety, and training.

Additionally, fratricide and other error related incidents have implications for joint operations. Of these four areas, only safety is a historical CRM concern. If one is to understand significance of identifying human error types in military aviation, it is important to understand the evolution of CRM and how it relates to military aircrew training and error reduction.

CRM has evolved primarily due to the changing nature of aircraft accidents. The early 1920s (considered the dawn of commercial and military aviation) were characterized by many accidents, mostly related to aircraft or power plant (engine) failure. The technology was new and so was the accident investigation process. As civilian aviation moved into the 1990s, this number dropped dramatically, but the number of accidents does not tell the entire story. As the number of aviation accidents fell, the percentage of accidents that were caused by human error rose to their current level of nearly 80 percent.[20] The primary cause of civilian and military aviation accidents has shifted from mechanical failure to human error, and further, this trend exists across the spectrum of aviation types. The United States Air Force, a subset of military aviation, shows the same trends. There has been a declining accident rate over time, generally speaking. However, in spite of the overall improving trend in aviation safety, the rate at which the human element is failing has not gone down. On the contrary, as the complexity of the aircraft and mission increases, the human ability to manage this complexity appears not to have kept up.

Today's advanced materials, engineering, all weather capabilities and maintenance schedules make aircraft hardware failures

in today's military almost nonexistent. The end result of these improvements is an impressive safety record for modern aviation, which has allowed the aviation community to turn even more attention to human factor concerns such as aircrew error. A noted aviation psychologist stated at an airline evaluators workshop, "As early as World War II, it was realized that the limiting factor in the development and the design of airplanes was the ability of the human to effectively operate and manage the resources provided."[21] As the nation moved from the post-war years into the 1950s, 1960s, and 1970s, the overall percentage of aircraft accidents listing lack of effective use of resources by the cockpit crew as a primary cause, grew until it became the major causal factor.[22] DESERT SHIELD/STORM provide the first opportunity in recent history to gain valuable insights on the nature of aircrew error in combat.

Armed with this background in the history of training against aircrew error, the significance of this study can be succinctly stated in the following argument. First, in spite of the tremendous success of USAF aircrews in the Gulf War, many errors did occur, some resulting in the loss of valuable equipment and irreplaceable lives. This perspective will add to a more holistic historical account of the Gulf War. Second, an analysis of these errors may lead to the development of a greater understanding of the types and nature of errors committed by aircrews on the modern air battlefield. Third, identified errors provide definable end states and objectives for current and future training programs. Finally, reduced aircrew error will result in improved mission effectiveness through:

1. The preservation of valuable national resources through improved safety

2. More effective training through better communication and reduction of instructional errors

3. Improved combat effectiveness through a greater mission completion rate, improved coordination and interaction skills, and increased self confidence.

Assumptions

This study assumed that all critical incidents listed by aircrew members relate actual occurrences. Since the reports were anonymous, there would be no apparent reason to relate a false occurrence. The researcher also assumed that all aircrew members were current and qualified in the aircraft they were flying. This assumption needs to be made because errors that occurred relating to *proficiency* must be analyzed against a baseline. A third assumption was that aircrew members were sincerely trying to accomplish the mission. Errors that occurred which prevented mission accomplishment were not deemed to be intentional as a means to avoid the combat environment. This is an essential assumption, because if the errors were intentional, they would not be errors at all. Finally, it is assumed that the aircrew members who reported the critical incidents could be classified as "expert observers" and eyewitnesses, fully capable of spotting the errors as they occurred.

Delimitations

Although this study will analyze several different types of aircrews from different aircraft, a specific breakdown of error type by cockpit type is beyond the scope of this study. Generalizations and implications that emerge from the data will be stated regarding mission types, but breakdowns by aircraft type will not be accomplished.

Although the means exists to track data from the critical incidents to specific organizations and operating locations, a discussion of organizational climate or cultural norms with regards to these data will not be included in this discussion. Ethical considerations regarding the anonymity of the respondents prevents this type of analysis.

Although in many cases military rank was mentioned in the critical incident, the concepts of crew or flight position, for example "aircraft commander" or "flight lead," were more appropriate than military rank for discussing and analyzing the data. Therefore, no attempt to provide an analysis based on military rank was attempted.

Limitations

To allow the widest possible exposure and dissemination of this thesis, this thesis will be kept unclassified. Detailed discussion of weapons and tactics are generalized and kept at the unclassified level. Although this made a full discussion of *mission effectiveness* somewhat less complete than a classified report, it was deemed an appropriate limitation to facilitate the dissemination of the finished product.

All of the critical incidents were analyzed by a single analyst. Ideally, a minimum of five trained analysts would compile and

rate each of the incidents, and a statistical analysis of their ratings would be accomplished. Time and manpower constraints prevented this type of analysis. Appropriate techniques for data analysis by an individual were applied, however, and are discussed in detail in Chapter Three--Methods.

Definitions

Aircrew. As used in this thesis, any individual or collection of Air Force personnel who fly together to accomplish an Air Force flight mission.

Cockpit/Crew Resource Management (CRM). The effective use of all available resources--people, weapon systems, facilities, and equipment, and environment--by individuals or crews to safely and efficiently accomplish an assigned mission or task.

Combat Effectiveness. The degree to which the aircrew accomplished a specific set of combat objectives, for example, did the aircraft strike assigned targets?

Crew Coordination. A set of communication skills used by aircrews to work together and facilitate sychonized activity.

Critical Incident. In this study, it refers to a short synopsis of an event that deviated from standard operating procedures. When giving directions to respondents, the definition was intentionally left vague to get the maximum latitude in responses. Below is an example of a critical incident used in this study.

INCIDENT NUMBER: 02 DESERT SHIELD/STORM: yes
BACKGROUND: B-52 was coming to it's third refueling and crew was tired. It was at night and the Aircraft Commander had 1 hr. in left seat. Aircraft Commander was having difficulty completing the refueling. The Aircraft Commander couldn't maintain the contact

position for more than a few seconds, though the copilot was probably capable of completing the refueling.
BEHAVIOR: The Aircraft Commander refused any help.
CONSEQUENCE: The aircraft came within 5 minutes of diverting to Saudi instead of landing at Garcia. Eventually the refueling was accomplished.

Human Factors. Conditions based on individual or team attributes and limitations which affect the human-machine-mission-management relationship. These conditions may include a combination of physical, physiological, psychological, psycho-social, and/or environmental elements which may be actual or perceived.

Expert Observer. In this study, it refers to an aircrew member, current and qualified in the aircraft in which he observes a critical incident as an eye witness.

External Criticism. A technique used to analyze the origin and authenticity of evidence.[23]

Internal Criticism. A technique used to analyze the "accuracy, trustworthiness, and sincerity" of evidence presented in an argument.[24]

Mission Effectiveness. The combination of combat effectiveness and training effectiveness.

Situational Awareness (SA). In flying, this refers to an aircrew member's continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the ability to forecast, then execute, tasks based upon that perception.

Training Effectiveness. The degree to which the aircrew accomplished available training on a given mission.

Summary

The history of the United States Air Force's performance in DESERT SHIELD/STORM has been only partially examined. A careful

analysis of tactical aircrew error in the Gulf War will yield valuable insights into the inner workings of an aviator's decision making skills, judgment, and performance under stress. Additionally, these findings can be used for purposes beyond the mere completion of a historical picture. Current training efforts underway to improve aviators' combat capabilities will benefit directly from a greater understanding of aircrew error.

CHAPTER TWO

REVIEW OF THE LITERATURE

In this chapter, human error is examined from general to specific. The traditional literature review approach will be used, where human error will be discussed in terms of previous research. Included in this discussion will be results of research done in industry, maritime operations, and other related fields. This will produce a better understanding of the categories, causes, and results of human error in general. Armed with this basic background, a more specific historical overview of military error in war will be accomplished, using patterns identified in the first section as a theoretical framework for the historical discussion. The purpose of the historical overview is to set the stage for an interpretation of the critical incidents which comprise the data for this investigation. The distinct historical implications of error on the battlefield is discussed. A discussion of tactical implications as well as the tragic results of battlefield mistakes known as "friendly fire" or fratricide is covered in some detail. This section concludes with a historical review of tactical aircrew error. Figure 2 illustrates the approach, showing the literature review beginning in the general area of human error, and moving towards the specific target area of tactical aircrew error.

This will contextualize the error analysis in later chapters and serve to provide a comparative framework with tactical military errors from other historical periods and conflicts. Chapter Two will conclude with a summary of relevant theory and set the stage for Chapter Three--Methods.

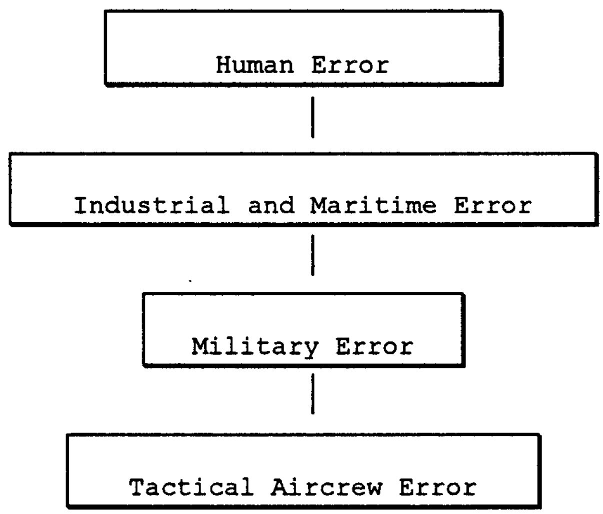

Figure 2. Diagram of the Literature Review.

Human Error

Human error permeates every aspect of society. Because this study focuses on tactical aircrew error, the discussion of error will be limited to related fields, such as industry, using examples to illustrate various categories of error. This review will demonstrate that while error is a much studied phenomenon, there has emerged no single, accepted method for classifying error. It is left for the researcher to choose among those offered in the literature, or to develop his or her own. Some of each has been done in this study.

Let us begin by asking two simple questions. "What is human error?" and "How bad is the problem of human error?" Webster defines error as, "an act or condition of often ignorant or imprudent deviation from a code of behavior."[25] There are two key elements of this definition that lead to a generalized discussion of the nature of human error. The first is the term "ignorant," which implies that the error-makers did not know, or was incapable of knowing that the action they were taking would result in an error. This lack of knowledge roughly equates to the concept of a loss of situational awareness (SA) in aviation jargon. It may well be that the error *per se,* occurred in the loss of SA and not in the subsequent action, but that "chicken or the egg" question is best answered by others. For the purposes of this study, an error is an error. The second part of the definition that needs clarification is the concept of imprudence. This implies that the error-maker knew and understood that his actions may result in an error--but took the action anyway. This leads to a discussion in tactical aviation about "judgment" and "risk management." The important key to discriminating between these two most basic classifications of error is intentions. In the case of lost SA, there is no intentional deviation from the standard. An example can help illustrate this difference. Assume for simplicity, that regulations prohibit a pilot from flying within ten miles of a thunderstorm. Pilot Bob flies within ten miles of the storm because he has not adequately "tuned" his radar, and is therefore, unaware of the danger. The error is in Bob's failure to realize he has insufficient information, but an error is committed nonetheless. Pilot Sue, on the other hand, is fully aware of the

location of the thunderstorm, but flies within ten miles because she needs to get home to see her son's soccer game. This is clearly an intentional deviation and brings up the issue of judgment. The demonstration of what *is* and *what is not* sufficient justification for deviating from established regulation or procedure is situational. For the purposes of this study, all critical incidents which identify deviations without justification statements are classified as errors. This appears to be a rational approach inasmuch as the reporters of these incidents were fully trained aircrew members and eyewitnesses to the event. If they deemed the action worthy of reporting as a significant deviation, this study will not second guess them. But the question, "What is error?" has only been partially answered. There are other sub-categories within this basic definition of error that are germane to this study.

One of the most flexible and elegant explanations of human error is outlined by J. W. Sender, a prominent researcher in aviation psychology. He breaks down error into categories of perception, execution, and intention. Senders uses a traffic light analogy to outline the difference between each.[26] Let's assume that Bob (after he lands and debriefs) is driving home and sees a red traffic light. He correctly decides to stop, but accidentally steps on the accelerator instead of the brake. This is an error of execution. In aviation these errors are often (but not always) tied to training, currency, and proficiency. On the other hand, if Bob had been looking into the sun and misperceived the red light as green or yellow, he would have committed a perception error. These errors are usually associated with

human factors engineering and ergonomic issues in aviation, such as field of vision, accessibility of gauges and readouts, or software displays. However, if Bob was just in a hurry, correctly saw the light as red and yet decided to go through it anyway, he would have committed an error of <u>intention</u>. In aviation, these are the most difficult to address and are one of the principle targets of CRM training.

The next level of discretion is primarily concerned with the *source* of error. An error that occurs because of internal personal factors are called endogenous. If Sue's desire to get home to see her son's soccer game led to an unacceptable risk being taken, she would have committed an endogenous error. These errors are also the traditional targets of CRM training. Exogenous errors, on the other hand, arise from events outside of the person, for example, the sun in Bob's eyes as he approached the stop light.[27] One final taxonomy will complete the discussion on the generalized nature of error and is important to our later system of classification of the critical incident data.

The nature of error lends itself well to four basic categories. Errors of <u>omission</u> occur when someone fails to accomplish a required task. In aviation this is often fatigue or complacency related. An error of <u>repetition</u> is when something is done over, once it has already been done. Closely related is an error of <u>insertion</u>, when something is done that should not have been done. These errors are associated with monitoring and crew coordination in the aviation realm. Finally, if the wrong thing is done at the right time, an error of <u>substitution</u> has been made.[28] These errors are often the result of a phenomenon called

negative transfer of training, which occurs when aviators take habits from one type of aircraft and incorrectly apply them to another.

Human Errors vs. Accidents

Although errors are deceptively easy to classify, they are extremely difficult to predict, and often even more difficult to correct. Because of the situational nature of error, there are literally infinite numbers of actors and variables in the error equation. This has caused many psychologists and training experts to begin to approach the problem of error identification and eradication as one of pattern recognition rather than an "if-then" cookbook (or checklist) approach to behavior modification. But the first challenge is to get professionals to recognize the magnitude and potential consequences of the problem of human error. Resources tend to be expended on error reduction only following an accident or incident. Sender states:

> the study or error is inextricably mixed with the study of accidents. Accidents are not psychological events. They are mostly physical events. Not all accidents are the result of error; not all errors lead to accidents. The latter is most fortunate since if all errors did result in accidents, aircraft would be raining down from the skies like leaves in a fall wind.[29]

These remarks ring true. But it also remains true that most evidentiary data on error come from accident investigations. Although this study will deal with critical incident data that did not, in most cases, result in accidents, an overview of the recent history of industrial safety will provide valuable insights as to the breadth and scope of error in the workplace. It will also serve to contextualize the study of aviation error and show that aviation error is not fundamentally

different than error found in other areas of industry. With the possible exception of the combat environment (stress level) and the accelerated dynamics of the flight regime, the theories of error discussed above are as useful for aviators as for those studying error in other fields.

Industrial Human Error

Now that the question "What is human error?" has been answered, the second question is, "How bad *is* the problem of human error?" One input to this answer comes from a look into the nature of recent industrial safety data to demonstrate that aviators are not the only ones suffering from the problem of human error. The analysis of maritime safety data is illustrative. In 1992, the shipping industry experienced one of the worst safety records in recent history, resulting in the deaths of 1204 people through a rash of collisions, fires, and "foundering" (sinking).[30] Lloyds Register, considered a benchmark measuring stick for maritime safety, shows that human error was a causal factor in over 80 percent of these accidents at sea.[31] This number is nearly identical to those identified in aviation safety studies. In a separate longitudinal study, "a review of major insurance claims in the shipping industry revealed that the number of human error incidents outweighed claims related to equipment and machinery failure by (a ratio of) five to one."[32]

Similar results are found in studies on vehicular accident rates on land in the transportation industry. "Highway accidents are the leading cause of death in the industrial setting."[33] This has led

to a radical shift in training focusing more on human factors training and error recognition and prevention.

One of the most alarming and illustrative incidents in industrial safety occurred in Japan's nuclear power industry. In early 1991, human error resulted in Japan's worst nuclear power accident at the Mihama Number 2 Nuclear Power Plant in Fukui Prefecture, Japan. Although it resulted in some radiation leakage, emergency cooling procedures were correctly employed to narrowly avert a complete meltdown and a disaster.[34] The resulting public outcry threatened to derail the entire nuclear power industry in Japan. This type of high-profile accident or incident can have lasting and far reaching implications.[35] A parallel could be made between this incident and two USAF incidents that have received great publicity. The mid-air collision between a F-16 and C-130 at Pope AFB resulted in the deaths of several military personnel. Likewise the "friendly-fire" shoot down of two U.S. Army Blackhawk helicopters put U.S. Air Force operations and training procedures under a microscope in the media. We will discuss this so-called "CNN Syndrome" more in Chapter Five.

Perhaps the single most watched human error accident in history was the tragic disintegration of the Space Shuttle *Challenger*. The human errors in this case were two-fold. Poorly trained and understaffed inspectors were unable to detect an "O-Ring" defect that was the ultimate cause of the tragedy, but managerial personnel also shared the blame for ignoring many indicators that the inspectors were understaffed and overworked. Additionally, the staff ignored or dismissed warnings about the temperature at the time of liftoff. The

Challenger disaster has become synonymous with human failing in high-tech operations, and an overhaul of NASA procedures was accomplished in its wake.

In answering the question, "How bad is the problem of human error?" it has been shown that error has dramatic impacts on operations as simple as operating a forklift, to the pinnacle of high technology, space and nuclear operations. It should come as no surprise that human error in the military has profound, and often tragic historical implications.

History of Military Human Error

A historical analysis of human error in battle provides the researcher a long list of anecdotal evidence, ranging from Hannibal's lack of siege warfare apparatus, to Lee's decision to send Pickett across open terrain. In spite of the relative abundance of historic case studies, few of these analyses were of utility for the purposes of this study. There are two reasons for this apparent contradiction. First, many historical analyses focus on command issues, often to the exclusion of discussing the tactical battlefield errors made by the individual soldier or airman, which is the focus of this study. The second, and more important reason, is that there has been little systematic historical recording of tactical error. There was with one notable exception--fratricide statistics. I have chosen to use these statistics as a benchmark of past military human error because it represents the closest approximation of a systematic identification of error types on the battlefield in a historical context. The most complete review of fratricide uncovered in the course of a reasonably

thorough literature search, was Amicicide: The Problem of Friendly Fire in Modern War, by Lt Col Charles Shrader, of the U. S. Army Combat Studies Institute. For the purposes of this study, the terms amicicide and fratricide are synonymous and interchangeable. This study looks at trends in fratricide statistics from ground and air forces from WWI through Vietnam. The statistics will be summarized by type (i.e., air, ground, etc.) and conflict searching for themes or trends relative to human error types.

Artillery Fratricide

Fratricide statistics from indirect fires show that human error is the primary cause of "friendly fire" casualties. World War I showed that a large number of artillery fratricide casualties may have been due to the "limited perfection" of communications technology and tactical doctrine for the control of indirect fires.[36] Shrader maintains that, although accurate fratricide statistics were not kept in WWI, actual fratricide events were quite commonplace.

> Postwar memoirs of participants on both sides attest to the frequency with which troops were fired upon by their own artillery. Indeed, when estimating the probable human cost of an offensive operation, the thorough staff planner usually included an allowance for casualties due to a friendly barrage.[37]

This statement highlights the scope of the problem and provides tangible evidence that fratricide was a common occurrence from indirect fires in WWI.

In WWII many of the technologies had advanced significantly since the "War to End All Wars," but artillery fratricide continued to be a problem.[38] Terrain appeared to make some difference in the frequency of fratricide. There were fewer instances reported in the

desert regions of North Africa than in either Europe or the Pacific Theaters. In these regions, the implications of the incidents give a hint of the impact human error can have on an overall operation. In one particularly telling example, the 85th Infantry Division suffered "four separate instances of artillery amicicide (fratricide) on the steep slopes of Monte Altuzzo."[39] This resulted in withholding of artillery support for a considerable part of the remainder of the offensive operation, and eventually the halt of <u>all</u> indirect fire support.[40] This fear of friendly fire severely hampered the 85th ID.

The Pacific theater was not immune to the effects of fratricide on the morale of the troops. One case study demonstrates that fratricide can have a detrimental impact on joint operations, an ominous harbinger for the future. During the invasion and seizure of Saipan, Army Maj. General Ralph Smith was relieved of his command by Marine Lt. General Holland Smith, in part due to the "constantly erratic artillery fire of the 27th Division into the Marine units on its flanks . . . animosities between the Army and the Marines soured their relations in the subsequent months."[41] As in WWI, the primary causes of fratricide were human coordination errors in the fire control network.

There was little change in the Korean War with regards to fratricide statistics and causes. Artillery technology was much the same as it had been in WWII. The rugged Korean terrain made indirect fire difficult and coordination extremely important. The battle of Pork Chop Hill, a confusing affair that involved trench and bunker battles with intermingling enemy and American lines, resulted in dozens of fratricide casualties as a result of poor coordination.[42]

The Vietnam conflict sheds new and important light on the ability of technology to overcome human error. "Improvements in technology were complemented . . . by an increased awareness at all levels on the need to protect friendly forces and noncombatants from the unintentional exposure to friendly fire."[43] Many extremely restrictive rules of engagement were implemented to the point that some officers claimed that their ability to utilize the superior American firepower was "unduly limited."[44] The result of this increased technology and restrictive rules of engagement was not a reduction in the frequency or severity of fratricide. On the contrary

> the available data suggest that the weapons and procedures of modern indirect fire artillery have become so complex as to exaggerate and compound the most persistent cause of artillery amicicide: human error.[45]

Shrader identifies several common human factors errors as prevalent across the spectrum of artillery fratricide: forward observer mistakes, fire direction center (FDC) miscalculations, failure to follow established procedures, fire control network coordination errors, and gun crew errors.[46] Table 1 breaks down the operation types and causes of artillery fratricide from WWII through Vietnam.

Aircraft Fratricide

It will come as no great surprise that the statistics from aircraft fratricide also show individual human error as the primary cause. There is one notable difference--the role of reduced visibility. Casualties from the air were far more damaging than those of artillery. Shrader explains:

> in terms of the number of friendly casualties caused, air incidents clearly predominate, both as to total casualties and casualties per incident. In one WWII incident alone, 111 friendly troops lost their lives and 490 more were wounded.[47]

TABLE 1

ARTILLERY FRATRICIDE

A. Conditions of Visibility

Conflict	Visibility Normal	Visibility Reduced	Visibility Unknown	Total Incidents
WW II (Eur)	9	7	4	20
WW II (Pac)	18	4	6	28
Korean War		3		3
Vietnam War	2	11	34	47
	29	25	44	98
	(30%)	(25%)	(45%)	(100%)

B. Type of Operation

Conflict	Defensive	Offensive	Patrol	Retro-grade	Type Unknown	Total Incidents
WW II (Eur)	3	13	1	2	1	20
WW II (Pac)	5	21	1	1		28
Korean War	3					3
Vietnam War	16	5	3		23	47
	27	39	5	3	24	98
	(28%)	(40%)	(5%)	(3%)	(24%)	(100%)

C. Type of Error

Conflict	Misident-ification	Mechan-ical	Coord	FDC	Crew	FO	Type Unknown	Total Inci-dents
WW II (Eur)			10	1			9	20
WW II (Pac)	2	1	13				12	28
Korean War			2				1	3
Vietnam War	1	4	7	4	9	9	13	47
	3	5	32	5	9	9	35	98
	(3%)	(5%)	(33%)	(5%)	(9%)	(9%)	(36%)	(100%)

Source: C. R. Shrader, Amicide: The Problem of Friendly Fire in Modern War (Fort Leavenworth: Combat Studies Institute, 1982) 27.

Fratricide incidents from aircraft were relatively few in WWI, as the aircraft had not yet matured in its air to ground mission. "Amid the tremendous casualties incurred by ground weapons, the deaths and wounds attributed to friendly air strikes went almost unnoticed."[48] In the next war, however, the role of the aircraft had grown.

WWII was resplendent with examples of fratricide from the air ranging from the tragic to the almost humorous. One example tells of a German ship which was loaded with allied POWs in Tunis on 4 May 1943. While at anchor for over three days, the ship was continually strafed by "at least forty allied fighters and over 100 bombs were aimed at the target. Fortunately, the fighter pilots proved somewhat unskilled, only one of the bombs, a dud, hit the ship, and only one of the allied POWs was killed."[49] This example highlights the difficulty of positive target identification from the air, a primary difference between ground and air fratricide.

WWII also marked the beginnings of close air support (CAS) doctrine development in a concerted effort to avoid fratricide. A "slow but steady" improvement in coordination between ground and air forces during CAS operations was seen. The one exception to this was an attempt to use heavy bombers in a CAS role, bombing from high altitude.[50]

Noncombatants also suffered the effects of human error from the air.

> As a result of a gross error--due to poor navigation, poor headwork and mis-identification of target, one group of medium bombers from the 9th Bombardment Division hit the Belgian town of Genck, twenty-eight miles west of the assigned target (emphasis added) on the morning of 2 October 1944, killing thirty-four civilians and wounding forty-five.[51]

This example illustrates three error types that were prevalent in WWII and remain as common causes of fratricide across the historical spectrum: navigation, judgment, and target identification. The Pacific theater complicated the pilot's task with often heavy jungle foliage, a problem American fliers would face again a quarter of a century later.

Fratricide statistics from the Korean conflict did not significantly differ from WWII. It is noteworthy, however, that Korea saw the introduction of the helicopter and jet fighter-bomber to the battlefield, both of which offered unique human factors challenges that were to surface in later conflicts.

Vietnam saw advancements in weapons technologies that made fratricide incidents far more damaging. Cluster Bomb Units (CBU) and napalm bombs had devastating effects. There were twenty-three casualties when a forward air controller (FAC) "failed to clear a target area properly and permitted an F-100 pilot to dump two CBU-2As in what the FAC *presumed* (emphasis added) to be an authorized jettison area."[52] This incident points to the error of "the faulty assumption" which is a form of lost situational awareness.

Vietnam also showcased a new type of warfare--the air assault. Helicopter door gunners often found it impossible to control their lines of fire as the helicopter hit air pockets or changed altitude rapidly. On several occasions, these problems resulted in gunners killing troops that had just left the aircraft.[53]

In general, the Vietnam conflict identified error types that are typical of those identified in safety mishap investigations in recent years. Lack of crew coordination, mis-identified targets,

disorientation, loss of situational awareness, navigation errors, and perception problems all are identified as leading to cases of fratricide.[54] Table 2 outlines air amicicide incidents by conditions of visibility, type of ground operation, type of air operation, and type of error.

Tactical Aircrew Error: The Fallacy of "Pilot Error"[55]

There has been a tendency throughout recent history to write off a multitude of complex physical and psychological error types into a single category--pilot error. The problem with this approach is that it focuses on "fixing the blame" rather than identifying the problem. In addition, it explains little of value to prevent future error occurrences. It has been this researcher's experience that "pilot error" may often be used to exonerate training, supervision or maintenance from the stigma of association with a mishap. This does not insinuate a cover-up of any kind, but does suggest an overly simplistic, non-beneficial approach on the part of mishap and accident investigation boards. Recent studies from aircraft mishap investigations have continued to identify aircrew error by type, but often, human factors experts must sift through the voluminous reports to isolate the actual cause and effect activities leading up to the mishap. A B-1B accident in the mountains of west Texas on November 30, 1992 was identified as "pilot error" in the Air Force 110-14 accident investigation report. A careful analysis of the flight profile hinted strongly at lost situational awareness, mis-

TABLE 2

AIR FRATRICIDE

A. Conditions of Visibility

Conflict	Visibility Normal	Visibility Reduced	Visibility Unknown	Total Incidents
WW II (Eur)	18	25	10	53
WW II (Pac)	17		7	24
Vietnam War	1	6	15	22
	36	31	32	99
	(37%)	(31%)	(32%)	(100%)

B. Type of Ground Operation

Conflict	Defensive	Offensive	Patrol	Retrograde	Type Unknown	Total Incidents
WW II (Eur)	5	39			9	53
WW II (Pac)		18			6	24
Vietnam War	2	5	1	1	13	22
	7	62	1	1	28	99
	(7%)	(63%)	(1%)	(1%)	(28%)	(100%)

C. Type of Air Operation

Conflict	Bomb	Strafe	Rocket	Bomb & Strafe	Type Unknown	Total Incidents
WW II (Eur)	32	12		5	4	53
WW II (Pac)	11	8	1	2	2	24
Vietnam War	9	10	3			22
	52	30	4	7	6	99
	(53%)	(30%)	(4%)	(7%)	(6%)	(100%)

D. Type of Error

Conflict	Misidentification	Mechanical	Coordination	Pilot-Crew-FAC	Type Unknown	Total Incidents
WW II (Eur)	8	4	10	13	18	53
WW II (Pac)	1		3	3	17	24
Vietnam War	2	2	10	7	1	22
	11	6	23	23	36	99
	(11%)	(6%)	(23%)	(23%)	(37%)	(100%)

Source: C. R. Shrader, Amicide: The Problem of Friendly Fire in Modern War (Fort Leavenworth: Combat Studies Institute, 1982) 27.

perceived cues from the aircraft, and spatial disorientation, none of which were identified in the official report.[56] The concept of blaming the cause of an accident on "pilot error" is of no greater value than if we said "the airplane broke" and did not identify the failed mechanism or part. One value of error identification studies like this one is to provide up-to-date tools for accident and mishap investigation boards to use instead of relying on the fallacy of pilot error.

Taxonomies of Tactical Aircrew Error

Recent studies have presented several taxonomies with which to categorize aircrew error. Alan Diehl, an aviation psychologist with the USAF Safety Agency, recommends dividing tactical aircrew errors into three categories, namely, procedural activities, perceptual-motor activities, and decision making activities--what he refers to as "slips, bungles, and mistakes."[57] These categories are useful for our purposes because they hint at areas associated with our research questions. For example, perceptual errors are linked closely to situational awareness. A mis-perceived cue could cause a pilot to lose track of the current dynamic state of his mission. Bungles, or motor mistakes indicate the possibility of training or flight currency related errors. Mistakes, or decision making errors will focus on the issue of judgment, a critical component of USAF CRM training programs.

A second taxonomy is reported in the U. S. Army's Flightfax safety publication. It lists eight areas as crew errors responsible for the majority of accidents.[58]

Scanning. Improper direction of visual attention, or use of a scan pattern that is not thorough or systematic or with crew overlap.

Crew Coordination. Failure of crewmembers to properly interact (communicate) and act (sequence and timing) in performance of flight tasks.

Maintain/Recover Orientation. Failure to properly execute procedures necessary to maintain or recover orientation in the flight environment.

Preflight Planning. Failure to choose appropriate flight options for known conditions and contingencies and develop courses of action to maximize probability of mission accomplishment.

Inflight Planning. Improper modification of flight plan . . . in response to unanticipated events or conditions.

Estimate. Inaccurate estimation of distance between objects or rate of closure with objects.

Detect. Failure to identify . . . hazardous conditions inside or outside of the cockpit.

Diagnose/respond to emergency. Improper identification or response to an actual, simulated, or perceived emergency.

A final taxonomy of aircrew error was found in a 1951 study from the office of the USAF Inspector General (IG), titled *Poor Teamwork as a Cause of Aircraft Accidents.* This study covered a period from 1 January 1948 to 31 December 1951, and analyzed 7,518 major aircraft accidents.[59] This number alone illustrates how far we have come in preventing accidents. Although the study is somewhat dated, the human factors errors identified track closely with those seen in more recent accident analyses. The study found that four general areas; pilot proficiency, crew discipline, crew proficiency, and teamwork, were illustrative of the majority of human factors errors. But the study further developed these general categories to specific error types as follows:[60]

1. Not alert

2. Insufficient briefing

3. Did not turn back

4. Took over too late (instructors only)

5. Poor judgment

6. Used wrong corrective action

7. Weather related navigation procedures

8. Poor supervision by flight leader or pilot in command

9. Confusion over who had controls

10. Gave incorrect information

11. Poor teamwork

Summary

These error types provide a starting point for our analysis of aircrew error in OPERATIONS DESERT SHIELD/STORM. We began by defining error as, "an act or condition of often ignorant or imprudent deviation from a code of behavior." We then identified generalized human error types as those of perception, execution, and intention. An analysis of industrial and maritime safety demonstrated the scope of the problem of human error and further, that certain error types were seen across the spectrum of occupations. Finally, we discussed civilian and military aircrew error, noting several taxonomies that provide guidance for the initial analysis of data in Chapter Four--Findings.

CHAPTER THREE

METHODS

Introduction

This chapter describes the specific methods used in this study and demonstrate that this was a rigorous study, guided by established methods and tools. The chapter begins with a discussion of the basic research design and researcher qualifications, the bedrock for any study. Second, sampling, data collection and reduction, and analysis procedures are discussed, using actual examples from the study to illustrate the techniques. Lastly, validity and transferability are addressed, demonstrating that while the subject matter in this study is highly specialized, the findings hold relevance to fields of study outside of those represented in this report.

Research Design

This study followed the basic design of classification research using qualitative and cliometric tools for historical analysis. Cliometric analysis is defined by Barzun and Graff as "quantifying documentary materials" to provide new understanding of historical events or occurrences.[61] Critical incidents collected from aircrew members in OPERATIONS DESERT SHIELD/STORM provide the raw data and will be analyzed through qualitative analysis, or coding by error type, and then categorized by implications for mission effectiveness, safety, or

training. These findings are then displayed by percentages in tabular formats. Finally, implications of the findings will be discussed.

The nature of the data should determine the research methodology.[62] In this study the data lend themselves to three basic modes of inquiry, classification research, qualitative analysis of the raw data, and cliometric analysis and display. Let's look at each individually and discuss the rationale for its selection in this study.

Classification research is defined as "sorting out a collection of people or objects and of developing a set of categories among which you divide the collection."[63] Of course, there must be a purpose for the classification. In this case it is to provide a better understanding of the nature of aircrew error and broaden the historical perspective of the Persian Gulf War. Simon and Burstein list four uses of a classification scheme that are appropriate for our study:[64]

1. A classification allows one to deal routinely with individual cases. This allows someone who is not as familiar with the area of study to easily access accumulated stores of knowledge if he or she is simply able to identify the individual case as a member of a larger group. This is important in a field like military aviation, where many of the training personnel have a high turnover rate, and hence, do not often possess the required depth of knowledge to make subtle discriminations between types of errors.

2. Classification makes others studying in the field aware of subtle differences among the categories. In the case of military aviation, this will give instructors an excellent tool for recognizing

and debriefing aircrew errors. A study like this can also provide reference points for further study.

3. Classification aids summarization. In the case of this study, errors associated with training loss, for example, could be discussed with a common set of techniques for corrective action.

4. A classification may contain within itself the explanation of the phenomena. For example, if we discover that crew coordination errors tend to follow a pattern of a specific type of communication, we may have also discovered that the corrective action lies in reducing or eliminating that communication error.

While the research design is certainly the "blueprint" for the study, the researcher is the craftsman who must create the actual building. A knowledgeable and qualified researcher is critical to the overall value of the study.

Researcher Qualifications

Qualitative analysis, the technique of coding that is used to categorize and classify the data in this study, relies almost exclusively on the human instrument.[65] As such, it is extremely important in this study to outline the qualifications of the researcher.

"The instrument in naturalistic inquiry is not an operational definition of anything, but a sensitive homing device that sorts out salient elements and targets in on them."[66] In this study, the researcher served this function after completing several graduate level research methods courses as well as being very familiar with aviation and curriculum development subject matter. E. I. Eisner, a noted educational researcher speaks of "connoisseurship," or the ability of a

researcher to make "fine grained discriminations among complex and subtle qualities" relevant to subject matter under investigation.[67] As a career aviator and human factors expert who has specialized in identifying and reducing aircrew error, this researcher is qualified to make these discriminations.

In addition to the researcher's background in aviation human factors, he is also well grounded in basic research methods. He has completed eight graduate level courses in research methods, half of these courses were in qualitative or naturalistic inquiry or analysis.

Alfred Peshkin, a noted social scientist, points out that a qualitative researcher must keep track of his own subjectivity. The potential for bias, or failure to account for the researcher's subjectivity, in this study must be recognized. These data were filtered and analyzed by a single individual, and thus reflect this researcher's understanding and interpretation of aircrew error as contained in the critical incidents under analysis in this study. Although a larger analytical staff would have been preferred, with all interpretations subjected to statistical analysis to identify and accomodate for outliers, the resources for such an effort were beyond the scope of this study. To counter this potential individual bias, the researcher was systematic and focused in the application of all theory to the data, and welcomes other researchers to replicate the study to further validate the results. In the final analysis, this study represents the work of a single researcher, but one who has considerable experience and background in the field of study.

Sampling

The participants in this study were Air Force crewmembers. The exact number of participants is unknown because some crewmembers generated more than one critical incident report, and some crewmembers did not generate any. A total of 740 critical incidents were analyzed. The sample for collection of the critical incidents was based on availability of aircrew members at seven separate Air Force bases, but represented a cross section of experience and aircraft types. The units that were selected for sampling all had DESERT SHIELD or DESERT STORM experience, although not all crewmembers at these units had been to the war.

The crewmembers sampled came from four aircraft. The sample came from bombers (B-52), fighters (F-16, F-111), and transport aircraft (C-141).[68] The aircrew members were all "current and qualified" in the aircraft on which they were reporting the critical incidents. That is to say that they were fully trained and authorized to conduct missions in their respective aircraft.

The sample include various crew positions and experience levels, including instructors, aircraft commanders and flight lead qualified pilots, co-pilots, navigators, and other crewmembers (loadmasters, flight engineers, etc.). Rank structure ranged from enlisted ranks through full colonel. Precise demographic data on the sample was unavoidably incomplete, due to safeguards to protect anonymity.

Data Collection and Reduction

The data were collected in the form of critical incidents, a short narrative of an event that "has been of decisive significance for the success or failure of a given task."[69] The critical incident technique was originally used by J. C. Flanagan in the 1950s to study reasons for student pilot failures in training.[70] The technique has been used in hundreds of studies since then and has been found to be a reliable tool for analysis of many aspects of job performance.[71] In this study, critical incident data was compiled from a previous (and incomplete) study conducted at the USAF Human Systems Center (HSC) at Brooks Air Force Base, Texas. These data were collected for the HSC under a government contract by a private research firm to assist in studies on aircrew human performance in combat. The incidents were collected from aircrews within days of their return to their home bases from the Gulf region. A small group of researchers explained the critical incident technique to an assembly of aviators, and passed out the blank forms along with an example. The aircrews were told simply to report any incidents which had decisive significance in the success or failure of a mission. In all, 740 incidents were collected. They were formatted to have three specific parts: background, behavior, and consequence. The incidents were hand written on a critical incident form and are were transcribed by personnel at the Human Systems Center. None of the words were altered and the incidents remain in the exact words as written by the aviators. The following example shows the format of the critical incident report.

INCIDENT NUMBER: 00131 DESERT SHIELD/STORM: yes
BACKGROUND: IP chasing Flight Lead upgrade during exercise in Saudi Arabia. IP is mission CC, and briefed as a commout mission.

Flt lead upgrade starts talking on radios to vector tankers around when such action unnecessary. Attempts to call Flt lead on radio prevented by wafer switch left in intercom.
BEHAVIOR: IP tried to get on wing of Flt lead upgrade to take lead, selecting after burner and pulling 3 Gs at same time.
CONSEQUENCE: Engine compressor stalled and IP ended up not participating at all.

The critical incidents were collected from eyewitnesses to the events and represent documentary evidence to occurrences that in most cases would have gone unreported. Documents such as these provide a stable and often unassailable source of data.[72] By "unassailable and stable," Lincoln and Guba mean that the data from the document itself leave little room for argument and the same categories are used for each participant and report, lending them to an easy comparative analysis.

Following the collection of the data, the critical incidents were transcribed, in the exact words of the aircrew members, by researchers at the USAF Human Systems Center (HSC) at Brooks AFB in San Antonio. They were sorted by aircraft type and compiled using Microsoft Word 5.0 software. The only changes that were made to the original words of the aviators was when one of the researchers ran the data through a spell check with the word processor. It was deemed that this did not significantly alter the original data and it was in this format that the critical incidents came into the hands of this researcher on one 3.5 inch high density disk. A formal agreement to continue to protect the anonymity of the participants was the only restriction put on the use of these incidents for research or training use. During the course of the study, the incidents were re-numbered for ease of tracking and statistical analysis purposes, but have not been altered or paraphrased in any other way for this study.

Qualitative Analysis of the Critical Incidents

In order to classify the critical incidents into a useful form for this study, a qualitative analysis of each incident was accomplished. The first step was to sort the incidents into two categories, DESERT/SHIELD STORM and non-combat. Once this was done it was decided to limit the study to just those incidents that occurred during the Persian Gulf War period. It was found that several of the incidents that listed "no" next to the line titled *DESERT SHIELD/STORM*:, were in fact, valid incidents for this study because they took place in the theater of war and were combat or support related.

After this initial sort was completed, a second sort was completed identifying those critical incidents in which error occurred. Although there were many incidents that identified positive crew actions, the limitations and foci of this study required that they be left for later analysis in a separate study. What remained were over 230 incidents which represented aircrew member error during DESERT SHIELD and DESERT STORM. Many of these incidents contained multiple errors.

The research questions provided the guidance for the development of an initial matrix for the error analysis. Across the top of the matrix were the three implications under which the errors would be subdivided, mission effectiveness, safety, and training. Error types found during the literature review were placed along the vertical axis of the matrix. These included errors in perception, motor activities, procedures, judgment, communication, crew coordination, planning, briefing, detecting, pressing too hard, waiting too long to act,

improper corrective actions, complacency, situational awareness, and improper workload distribution. These codes were selected as a starting point, not only from the literature review, but also through a short "pilot study" of 75 critical incidents in which these codes were found to occur most frequently. The pilot study also assisted by increasing the researcher's proficiency in the coding process, giving him a chance to "warm up" and standardize his interpretation and techniques.

It became immediately apparent during initial data analysis that the researcher would require a separate matrix for each of the three areas addressed by the research questions. The separate matrices were titled <u>mission effectiveness</u>, <u>safety</u>, and <u>training</u>. The horizontal axis was now <u>perception</u>, <u>motor errors</u>, and <u>judgment</u>. The vertical axis remained the same, except to exclude the items placed along the horizontal axis.

Figure 3 shows the error analysis matrix for mission effectiveness. Identical matrices were constructed for safety, and mission efficiency.

It is readily apparent that many of these error types overlap. It also became apparent that there were some areas of error that did not fit easily into any of the categories listed. A short discussion of the coding process used will help establish how the data were classified and the evolving nature of the analysis.

Coding

Aslem Strauss, a social scientist specializing in qualitative analysis, states, "coding is a general term for conceptualizing data; thus [it] includes raising questions and giving provisional answers . .

. [about the data] and about their relations. A code is the term used for any product of this analysis."[73] The coding procedures used in this study can be divided into three distinct types, codes derived from existing theory located in the literature review (etic codes), codes which emerged from the data analysis (emic codes), and axial coding, which tied the analysis to the research questions and uses both etic and emic codes.

Mission Effectiveness

	Perception	Motor Errors	Judgment
procedures			
decision making			
communication			
crew coordination			
planning			
briefing			
detecting			
pressing too hard			
waiting too long			
corrective actions			
complacency			
situational awareness			
workload distribution			

Figure 3. Error Matrix

Strauss calls the decision about early coding techniques as among the most important. By selecting axial coding from the three research questions (i.e., mission effectiveness, safety, and training) the researcher "began to build up a dense texture of relationships around the axis of a category being focused upon."[74] Final selection of codes resulted in the identification and classification of the error types for the findings of this study. This final process of selective coding was used to home in on the central themes of the study. Strauss (1987) states "selective coding (is) when all categories and subcategories become systematically linked to the core."[75]

This rather tedious discussion of the coding process is designed to demonstrate that the researcher followed a detailed and systematic process of data analysis, and was guided by established theory. The rigor of the analysis allows the researcher to argue for credible and reliable findings.

After completion of the coding process, the results were interpreted and displayed, the results of which are found in Chapter Four--FINDINGS. The strength of the findings rests in the concepts of validity and transferability.

Validity and Transferability

Rigorous research yields truthful and transferable findings. Maurice Matloff, the Chief Historian at the Center for Military History outlines two criteria essential for truthful findings in historical research. Internal criticism is a technique used to analyze the "accuracy, trustworthiness, and sincerity" of evidence presented in an argument.[76] The two criteria used for internal criticism in this study were eyewitness accounts, and expert observers. Recall from Chapter I

we defined expert observer as an aircrew member, current and qualified in the aircraft in which he observes a critical incident. The second criteria was established at the time the critical incidents were collected. That was, to record a critical incident, one must have been an eyewitness to the event. No second hand accounts were allowed.

External criticism is a technique used to analyze the origin and authenticity of evidence.[77] Because of the careful "chain of possession" of the critical incidents used as data in this study, the external criticism criteria are strongly met. In short, we can trace the origin of these documents to the creators.

In the qualitative method, the term validity represents the "truth value" of the research findings. In short, "does the research measure what it claims to?" Lincoln and Guba argue for transferability as an analog to traditional external validity, or, "is this research useful beyond the narrow scope of the individual study?"[78] Despite the fact that these errors occurred in the cockpits of high tech military aircraft in a combat situation, the results of this study may have implications for others working in high-stress, time constrained environments. One of the strengths of using individual mini-case studies (the critical incidents), is that it allows others to determine how closely their own environment parallels the incidents described, and therefore, the degree of transferability.

The researcher argues for validity and transferability based on the strengths of his analysis, internal and external criticism criteria, and the mini-case study approach represented by the critical incidents.

Summary

We described the basic research design of this study as <u>classification research</u>, using historical and qualitative analysis tools. We looked at the researcher's qualifications, and found a solid grounding in aviation human factors and research methodology. Sampling, data collection, and analysis procedures were outlined, detailing the coding process utilized for data analysis. Lastly, validity and transferability were addressed, demonstrating that while the subject matter in this study is highly specialized, the findings will be truthful and may well hold relevance to fields beyond the narrow focus of this study.

CHAPTER FOUR

FINDINGS

Introduction

Airpower was a key to victory in DESERT SHIELD and DESERT STORM, but the errors committed at the tactical level identify areas that can lead to even further improvement in USAF capabilities. Chapter Four will present the findings of this inquiry regarding tactical aircrew error in the Gulf War. The historical overview in Chapter One emphasized the importance of airpower to the operation as a whole. The historical overview of DESERT SHIELD/STORM, the review of the literature on human error, and the explanation of the methods, have set the stage for the presentation of the findings on tactical aircrew error in the Gulf conflict. It will demonstrate the critical role played by USAF assets, and therefore the significance of tactical aircrew error. The specific error-type findings are presented in narrative and graphical formats, in the same order that the research questions were presented.

Aircrew Error in Operations DESERT SHIELD and DESERT STORM

The findings on aircrew error show that the most frequent errors made by crewmembers involved decision making, situational awareness, procedures, and crew coordination. This was true for all three areas of mission effectiveness: combat effectiveness, safety, and training. Approximately one-half of the errors had an implication for safety. The other half of the errors were split between combat

effectiveness implications, training implications, and a small number of errors that did not fit neatly into any of the three categories.

There were small differences between aircraft types in the types of errors committed, usually related to the type of mission flown by that aircraft or the nature of the crew composition. Although the differences between aircraft types were intriguing, they were not the focus of this study, and so they were left as implications for future research.

Virtually all of the error types identified are covered in current or planned Cockpit/Crew Resource Management (CRM) training programs, but the frequency of each error type by aircraft has implications for prioritization of the training. The study looked at crewmembers from four aircraft; F-16s, F-111s, C-141s, and B-52s. This gave the study a cross section of mission type and crew composition.

The presentation of the specific breakdown of these errors will follow the research questions outlined in Chapter One. They are restated below.

Thesis Question

What were the mission effectiveness implications of common error types committed by United States Air Force (USAF) aviators in OPERATIONS DESERT SHIELD/STORM?

Supporting Research Questions

1. What were the common error types committed by USAF aircrews in DESERT SHIELD/STORM?

2. What percentage of these errors affected combat effectiveness?

3. What percentage of these errors affected safety?

4. What percentage of these errors affected training effectiveness?

5. What are the training and curriculum development implications of these errors?

Error Types

The study identified twenty seven separate error types made by crewmembers. These were uncovered from the analysis of 456 critical incidents, of which only 264 contained identifiable errors. That is to say that nearly half of the critical incidents illustrated positive aspects of airmanship, but they were not the subject of this study. Within the 264 incidents, 778 errors were identified, for an average of 2.94 errors identified per incident. As described in Chapter Three, many of these errors were listed under more than one heading. For example, a communication error might also be a crew coordination error. This does not skew the data because the errors are interpreted in relation to the total number of incidents in which they occured. For example, decision making errors occurred in 36.4 per cent of the incidents.

The errors are categorized as either frequent, common, or infrequent. Frequent errors occurred in greater than 25 percent of the incidents. Common errors occurred in greater than ten percent but less than 25 percent of the incidents. Infrequent errors occurred in less than ten percent of the incidents. The errors are listed below, by

category, with a brief explanation of the specific error type. Examples are included for the frequent and common error types.

Frequent Errors

There were four errors which occurred in more than 25 percent of the incidents. They are described below with examples taken from the study.

Decision Making Error. The crewmember chose the wrong course of action. This occurred in 36.4 percent of the incidents and was the single largest error category identified in the study. The following example was a typical decision making error.

> INCIDENT NUMBER: 00159 DESERT SHIELD/STORM: yes
> BACKGROUND: Although no minimum altitude limits had been placed on missions, squadron leadership had stressed remaining above 8000'-10000' and limiting reattacks on targets. On a mission the wing commander launched a maverick at approx. 10000'. Coming off target he saw an enemy APC with troops getting out.
> BEHAVIOR: The wing CC immediately reversed and rolled in to gun the target pulling off at approx. 6000'.
> CONSEQUENCE: On pull off the wing CC took a SAM hit resulting in loss of hydraulics and significant battle damage. He was able to safely recover.

In this incident the pilot, who happened to be the wing commander, went against the stated policy of the squadron, and suffered battle damage, as well as setting a bad example.

Situational Awareness (SA) Error. An SA error is inaccurate internal perception of what is going on with the aircraft, crew, or other factors involved with a particular situation. These errors were seen in 33.3 percent of the incidents. The following example illustrates a loss of situational awareness.

> INCIDENT NUMBER: 00035 DESERT SHIELD/STORM: yes
> BACKGROUND: EF-111 night formation flight. 2 ship was practicing night rejoins at medium altitude over water. During the flight a circuit breaker had popped causing the anti-collision beacon and

position lights to be inoperative. Formation lights and strip lights were still working.
BEHAVIOR: As #2 closed, he climbed to lead's altitude to complete rejoin, giving no indication that he was aware of inoperative lights.
CONSEQUENCE: Near miss as the two aircraft passed 180 out (heading in opposite directions) without altitude separation.

This situation clearly indicates a loss of situational awareness with near tragic results.

Procedural Error. An error caused by not following the Technical Order or checklist. Procedural errors occurred in 32.2 percent of the incidents. The following example illustrates a typical procedural error.

INCIDENT NUMBER: 00052 DESERT SHIELD/STORM: yes
BACKGROUND: B-52 was refueling on the outbound leg of a combat mission. The plane was carrying over 40,000 lbs of conventional bombs. The refueling was planned up to the max flying gross weight of 488,000 lbs. The copilot allowed refueling up to 488,000 on the CG/FLAS (center of gravity and fuel advisory system).
BEHAVIOR: The copilot forgot to add the bomb weight into the CG/FLAS.
CONSEQUENCE: The actual refueled weight was well in excess of max allowable limit during EWO (emergency war order) operations.

In this situation, the copilot did not follow tech order guidance. His failure to do so placed the aircraft in an unsafe performance condition.

Crew Coordination Error. Distinct from communications, this error involved a failure to coordinate appropriately (i.e. at the right time and in the right amount) with a member of the flight team. This team could include crewmembers on the same aircraft, or be between aircraft in the same flight (i.e., lead to wingman in a formation of fighters). Crew coordination errors were identified in 27.7 percent of the incidents. The following example from a B-52 aircrew clearly demonstrates an example of poor crew coordination.

INCIDENT NUMBER: 00001 DESERT SHIELD/STORM: yes
BACKGROUND: A B-52 Aircraft Commander was flying a PAR in extremely poor WX at Diego Garcia. The situation involved a high

degree of stress, as there were several aircraft, low on fuel, needing to land. The approach was flown poorly causing the Aircraft Commander to become too flustered to complete the landing checklist.
BEHAVIOR: The Aircraft Commander told the copilot (who was running traffic pattern checklist) to shut up during the landing check.
CONSEQUENCE: The gear, flaps, etc. were never confirmed in landing configuration by either pilot.

This situation illustrates a failure of crew coordination. The pilot, in effect, prevented the copilot from accomplishing his duties during a critical phase of flight.

Common Errors

Common errors were those found in greater than ten per cent but less than twenty five percent of the incidents studied. There were five common errors uncovered in the course of this study. They are listed with examples and explanations below.

Communications Error. An error which involved ineffective, incomplete, or lack of communication. It could occur between crewmembers or from a crewmember to an outside agency, such as AWACS. This error was found present in 19.7 percent of the incidents. The following example is a classic communication error.

INCIDENT NUMBER: 00085 DESERT SHIELD/STORM: yes
BACKGROUND: An aircrew was flying into Cairo International and was cleared an approach that was not clear(clearly understood). The AC had never been there before while the copilot had. The AC interpreted the instructions one way and the copilot another. The copilot asked the AC to query the controller, which he reluctantly did. The copilot attempted to tell the AC what he thought the instructions were.
BEHAVIOR: The AC disregarded the copilot's inputs and did not attempt to clarify the instructions.
CONSEQUENCE: The Cairo controller came on the radio and asked the aircraft what they were doing and instructed them to proceed as the copilot had recommended.

The inability of this aircrew to communicate effectively led to a potentially hazardous misunderstanding with a foreign air traffic controller in a high density air traffic area. This highlights the

importance of effective communications both inside and outside of the aircraft.

Pressing Too Far. This error, which is a subset of the judgment/decision making error, occurs when a crewmember continues with the mission, or portion thereof, when good judgment dictates otherwise. It was found in 16.3 percent of the incidents and ranged from marginal judgment to severe recklessness. The following example illustrates the repercussions of pressing too far.

> INCIDENT NUMBER: 00144 DESERT SHIELD/STORM: yes
> BACKGROUND: On the last day of the war in Iraq a 4 ship of F-16s was trying to drop bombs on retreating Iraqis. Two days prior we were told to stay above 10,000'(a standard operating procedure [SOP]) and remember the war would be over in a matter of days so do not expose yourself unnecessarily. This talk was given by the wing DO and squadron CC.
> BEHAVIOR: The flight lead decided to descend into the wx and was shot down at approximately 7000'.
> CONSEQUENCE: A Helicopter was shot down trying to rescue the pilot (killing 5 on board).

This is a tragic example of a pilot who exercised extremely bad judgment by pressing too far on a mission that did not require it. The price he paid for this mistake was the loss of an aircraft and five lives.

Regulatory Deviation. This error involves the intentional violation of an existing regulation or rule of engagement (ROE). It was seen in 12.5 percent of the incidents. One example of a violation of ROE follows from an F-111 crewmember.

> INCIDENT NUMBER: 00044 DESERT SHIELD/STORM: yes
> BACKGROUND: ROE required positive radar/pave tack ID (identification) of the target area. WSO failed to achieve positive ID.
> BEHAVIOR: Pilot elected to drop bombs anyway.
> CONSEQUENCE: Assigned target not hit. Bombs may have impacted a civilian area.

This error could have had international incident implications, and illustrates the significance of this error type.

Flight Lead Error. A formation-associated error which impacted on the effectiveness or safety of a multi-aircraft formation which originated from the flight lead.

INCIDENT NUMBER: 00121 DESERT SHIELD/STORM: yes
BACKGROUND: F-16 wingman grounded for a day for descending below 10K' (in violation of SOP) during interdiction sortie into Iraq on a clear blue day. Flight commander then flew as his paired lead aircraft to watch his performance. Sortie flown using a FAC that gave coordinates to another target in Iraq. Wx was 8000' overcast.
BEHAVIOR: Flight commander led the wingman under the overcast into the target area and proceeded to circle the target twice to deliver ordnance while defending against AAA due to being highlighted against the clouds.
CONSEQUENCE: Both aircraft delivered bombs and RTB safely but put at unnecessary risk by flight commander who earlier the same day punished the wingman for the same type of action.

This example shows not only a flight lead error but also a supervisory error. This incident was also logged as a judgment/decision making error and a pressing too far error.

Weather Related Errors. These errors were identified in 10.6 percent of the incidents and are associated with poor or marginal weather conditions, which lead to crewmember difficulties. The following example is illustrative of this type of error.

INCIDENT NUMBER: 00112 DESERT SHIELD/STORM: yes
BACKGROUND: F-16 pilot was #4 in a 4-ship returning to the FOB after an interdiction sortie in southern Iraq. The wx was 1 mile in blowing sand. The pilot had INS and TAC problems and had difficulty determining his position after the flight split-up.
BEHAVIOR: After jettisoning his stores because of low fuel he finally spoke up on the radio.
CONSEQUENCE: #1 told him to tell the approach controller and request no-gyro vectors for a PAR approach.

Weather related errors often compound other types of errors, such as the equipment malfunctions in the case above.

Infrequent Errors

These errors occurred in less than 10 percent of the incidents. It is important to state that an infrequent error does not equate to an

insignificant error. The consequences of an infrequent error can be just as deadly as those of a frequent or common error. The following errors are listed in order of occurrence by percentiles.

Detection Error. A detection error is where a crewmember fails to observe a critical piece of information. It was identified in 9.1 percent of the incidents studied.

Complacency. Complacency is the lack of appropriate vigilance for a given phase of flight. Complacency was noted in 7.6 percent of the incidents.

Stress Related Error. This is an error in which the high stress of the situation appeared to play a major role in the crewmember's actions or inaction. This category was usually "dual logged" with another error type. This error type was also noted in 7.6 percent of the incidents.

Failure to Use Available Resources. This error was identified in 7.2 percent of the incidents, and occurs where the means existed to handle a given situation, but were not accessed or utilized.

Briefing Error. This is an error of commission or omission where a briefer fails to properly detail the requirements of a mission or part of a mission. It was identified in 6.1 percent of the incidents studied.

Workload Distribution Error. This is a failure to appropriately "share the load" during demanding portions of the mission. This error type was noted in 6.0 percent of the incidents.

Wingman Error. These errors are formation-associated errors which impacted on the effectiveness or safety of a multi-aircraft

formation, which were committed by the wingman. Wingman errors were identified in 6.0 percent of the incidents.

Distraction. Distraction errors are misplaced attention. They were identified in 5.7 percent of the incidents.

Delaying Actions. These are errors which occurred by not taking appropriate action in a timely manner, and they were noticed in 5.7 percent of the incidents.

Proficiency. Although all crewmembers were qualified in the aircraft in which they flew, some errors appeared to be caused by inexperience or just plain "bad flying." These errors were attributed to proficiency and were noted in 5.7 percent of the sample.

Anger/Yelling. This was a unique type of communication error, where one crewmember "lost his/her cool" and began to verbally assault another crewmember in an angry manner. It was seen in 5.7 percent of the incidents.

Planning Error. Not all errors took place while the crew was airborne. Planning errors involve preflight, as well as in flight mistakes in planning. They were identified in 5.3 percent of the cases.

Fatigue Related Error. Much like the stress related error, several incidents hinted strongly that fatigue played a causal role in the error. Fatigue related errors were seen in 3.4 percent of the incidents.

Supervision. A supervision error was associated with inappropriate guidance from a crewmember's command structure. It was seen in 3.4 percent of the incidents.

Not Sticking to the Plan. Some errors occurred because the crewmember deviated unnecessarily from the planned and briefed course of action. This was seen in 3.4 percent of the incidents.

Wrong Fix. At times, the crewmember took inappropriate action in response to a situation. The *wrong fix* error was noted in 3.4 percent of the cases studied.

Lack of Guidance. This was an error caused in part by the lack of a regulation or policy to address a given situation. It was seen in only 1.5 percent of the incidents.

Hot Dogging. *Hot Dogging* is an inappropriate action taken in an attempt to "show off." It is also a subset of the *judgment/decision making* error type. It was only noted twice, less than one percent of the cases.

Table 3 provides the numerical breakdown of the error types by aircraft type.

Error Types Percentages Associated with Combat Effectiveness, Safety, and Training

The implications of aircrew error on the three aspects of mission effectiveness were initially calculated by aircraft type, but no significant differences were seen. Safety implications were identified in 411 of the errors, or 53 percent. An example of an aircrew error with clear safety implications can be in the next incident.

TABLE 3.

AIRCREW ERROR SUMMARY

Error Type			Aircraft Type		
	B-52	F-111	C-141	F-16	Total
Decisions	19	26	24	27	96
Situational awareness	16	26	21	25	88
Procedures	25	17	19	24	85
Crew Coordination	20	10	29	14	73
Communications	12	10	17	13	52
Pressing too hard or far	7	14	10	12	43
Regulatory deviation	7	6	13	7	33
Flight Lead error	8	12	0	13	33
Weather related	0	7	15	6	28
Detection	12	1	9	2	24
Complacency	7	1	7	5	20
Stress	5	6	3	6	20
Use of available resources	3	2	11	3	19
Workload Distribution	6	4	4	2	16
Briefing	11	2	2	1	16
Wingman error	0	4	0	12	16
Proficiency	7	3	3	2	15
Anger/Yelling at others	9	0	6	0	15
Delaying actions	2	3	6	4	15
Distraction	4	2	5	4	15
Planning	1	7	5	1	14
Not sticking to the original plan	0	3	1	5	9
Supervision	0	3	6	0	9
Fatigue	3	0	3	3	9
Wrong Fix	1	4	3	1	9
No guidance from policy or regs	2	1	1	0	4
Hot dogging	0	2	0	0	2
Total	187	176	223	192	778

INCIDENT NUMBER: 00056 DESERT SHIELD/STORM: yes
BACKGROUND: A C-141 crew experienced a jammed aileron. The crew identified the wrong aileron as jammed.
BEHAVIOR: The AC de-activated the good aileron.
CONSEQUENCE: The aircraft began rolling out of control. The AC re-activated the good aileron, and eventually discovered error.

This error had clear safety implications, and had the aircraft been flying closer to the ground when this occurred, the results could have been disastrous.

Training effectiveness implications were seen in 187 of the errors, or 27 percent. In the following example, a formation flies in a less than precise manner. Although the mission is accomplished safely, the aircrews lose valuable formation training.

INCIDENT NUMBER: 00109 DESERT SHIELD/STORM: yes
BACKGROUND: While planning for a Desert Storm mission, after the aircrew were in a 24 hour plan-fly-debrief cycle, a B-52 AC of the 6 ship formation briefed the procedures for joinup after the final refueling prior to entering Iraqi airspace. The briefing took 5 min. as opposed to the 15 minutes the group had become accustomed to. The crews had never flown together before.
BEHAVIOR: During the brief, the leader skipped through most required briefing items and briefed others as "standard".
CONSEQUENCE: A rag tag formation was flown.

Some errors were seen to directly impact upon combat mission accomplishment, as the following example illustrates. There were 106, or 13.6 percent of these *combat effectiveness* errors identified.

INCIDENT NUMBER: 00095 DESERT SHIELD/STORM: yes
BACKGROUND: Lead of 3 ship B-52 combat mission at the formation brief talked about non-standard terminology and tactics. At best, confusing to the flight.
BEHAVIOR: In flight, lead performed unexpected climbs and turns, as if avoiding threats. (Lead never established himself over the IP, and may have dropped off-target).
CONSEQUENCE: #2 was so busy trying to find where lead was going, they never made it over the target, and withheld all weapons.

Seventy four of the errors (9.5 percent) could not be classified in any of the three areas. Figure 4.2 illustrates the breakdown of aircrew error by implication on mission effectiveness.

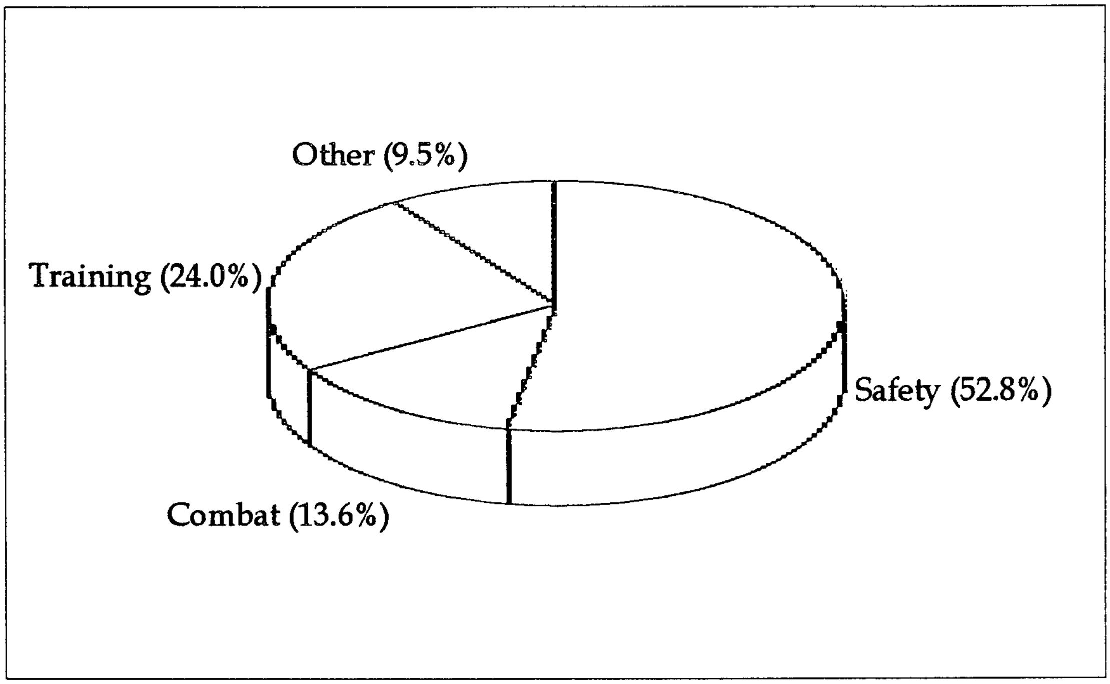

Figure 4. Mission Effectiveness Implications.

Training and Curriculum Development Implications

The current USAF human factors training program, Cockpit/Crew Resource Management (CRM), broadly covers all areas of aircrew error discovered in this study. Air Force Instruction (AFI) 3622-43 provides general guidance to the Major Commands (MAJCOM) for CRM curriculum development. The error types discovered in this study are listed below the applicable headings of AFI 3622-43. This is not meant to limit the scope of the AFI to these areas, but rather to provide useful guidance on how and where the results of this study might be put to practical use by MAJCOM curriculum developers.

6.1 **Situational Awareness.** A desired end state of CRM training is a high state of situational awareness. Tools for preventing lost situational awareness, cues for recognizing lost situational awareness, techniques for recovering from

lost situational awareness will be covered under this concept area.[79]

Applicable Error Types
•Situational Awareness
•Detection
•Distraction

6.2. **Group Dynamics.** Includes command authority, leadership, responsibility, assertiveness, conflict resolution, hazardous attitudes, behavioral styles, legitimate avenues of dissent, team-building, and desired traits.[80]

Applicable Error Types
•Crew Coordination
•Flight Lead Errors
•Wingman Errors
•Anger/Yelling
•Supervision

6.3. **Effective Communications.** Includes common errors, cultural influences, and barriers such as rank, age, and position, participation of all crew members. Also stress coordination with other participants in a mission, interface concerns, listening, feedback, precision and efficiency of communication.[81]

Applicable Error Types
•Communications
•Briefing

6.4. **Risk Management and Decision-making.** This includes risk assessment and risk management styles, process, tools, breakdowns in judgment and discipline, problem-solving, evaluation of hazards, and management of regulatory deviation during emergencies.[82]

Applicable Error Types
•Decisions
•Pressing too hard
•Regulatory Deviation
•Not Sticking to Original Plan
•No Guidance from Policy or Regulations
•Hot Dogging

6.5. **Workload Management.** This area covers overload, underload, complacency, management of automation, available resources, SOPs and checklist discipline.[83]

Applicable Error Types
•Workload Distribution
•Complacency

- Use of Available Resources
- Procedures

6.6. **Stress Awareness and Management.** Includes sources of stress, benefits and hazardous effects, and coping techniques.[84]

<u>Applicable Error Types</u>
- Stress
- Fatigue

6.7. **Mission Planning, Review, and Critique Strategies.** This area covers premission analysis and planning, briefing, ongoing or mid-mission review, and post mission critique. This area is intended to allow individual MAJCOMs and FOAs to include mission specific and weapon system specific planning, briefing and critique tools in their CRM training.[85]

<u>Applicable Error Types</u>
- Planning
- Wrong Fix
- Proficiency
- Weather Related

This analysis provides the opportunity for a more focused approach to training and CRM curriculum development than currently is available. The critical incidents reveal an inside look at the types of errors that were made in the combat environment of DESERT SHIELD and DESERT STORM. This data should prove useful in improving the human side of the combat performance equation.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This thesis has examined aircrew error from the historical perspective of DESERT SHIELD and DESERT STORM. The study has sought to identify some of the specific characteristics of aircrew error, in order to provide a more focused understanding of the phenomenon. Through the analysis of critical incidents provided by the crewmembers themselves, a clearer picture of the nature of aircrew error can be seen. In this chapter, the conclusions of this study are presented, along with some recommendations for their potential application. The chapter concludes with an overview of suggested follow-on research, and a final perspective, in hopes of continuing the quest towards improving the performance and capabilities of our aviators.

Conclusions

When USAF aviators make mistakes, bad things can happen to the mission. The results of this study clearly indicate that aircrew error effected the USAF's mission effectiveness in Operations DESERT SHIELD and DESERT STORM. The data indicates that error impacted upon all three areas of mission effectiveness: combat effectiveness, safety, and training.

Errors can be deadly. Safety was seen as effected most often by aircrew errors. Nearly 53 percent of the errors identified in this study held safety implications. It is interesting to note that within

the USAF human factors training arena, the safety officers have been the originators of most of the human factors training programs. Perhaps intuitively, they had surmised that a majority of aircrew errors resulted in potentially unsafe conditions. The increasing trend of human error as the primary causal factor in aircraft mishaps has also served to focus the attention of the safety community on error identification and prevention. The results of this study reinforce their efforts in this critical area.

Errors have a negative effect on training. The researcher found it somewhat surprising that there was such a large number of errors associated with training effectiveness. Twenty-four percent of all identified errors negatively effected the training environment. Communications errors, briefing errors, and crew coordination errors, were seen to have a detrimental effect on training. The focal points of the USAF CRM training effort now resides in the various MAJCOM training divisions, but many crewmembers and supervisors still see human factors training as linked exclusively to safety issues. The bottom line of USAF training is to get the maximum available training out of each flight. By reducing the errors which have a negative effect on training, the efficiency of training should go up, saving sorties, jet fuel, and dollars. All air crewmembers who are responsible for training others should receive this form of training as part of their career-spanning CRM training. For example, aircraft commanders, instructor pilots, navigators, etc., should all understand the role of specific types of error on effective training. Armed with this understanding, they could continually refine their instructional skills to produce the

most efficient training systems possible. The results of this study suggest that more emphasis in the area of reducing error to improve training would be warranted.

Some errors prevent the combat mission from being totally accomplished. These errors appeared in 13.6 percent of the incidents, and many had dramatic repercussions. The F-16 pilot who pressed too far, ended up being shot down. More tragically, this individual error led to the additional shootdown of a rescue helicopter who was attempting to rescue him, killing all five aboard. Other examples illustrated ineffective, or *inadvertent* weapons releases, some of which had the potential to cause an international incident. Although the USAF effort as a whole was a dramatic success, as evidenced by the historical overview at the beginning of Chapter One, there were numerous areas identified where further work needs to be done. Flight leadership, situational awareness, wingman errors, and pressing too far, were all seen to have a negative effect on combat effectiveness in many cases.

Recommendations

This study makes three recommendations. First, it recommends that a central point of contact be established to gather critical incident data from aviators at periodic intervals during peacetime, and during or immediately following any combat application of airpower. The critical incidents gathered following the Gulf War have proven to be a gold mine of data for improving the performance of USAF operations. In addition to the current study, they have been used to point out numerous command and control and supervisory problems, coordination issues, and to discuss rules of engagement. The critical incidents are also an

excellent method for preserving the history of a given event or time period for future study. The value of the self reported incidents is well worth the effort required to collect them. One possibility would be for the Air Force Systems Command to be resourced with the money and manpower to accomplish this worthwhile task.

The second recommendation is for MAJCOM training programs to include measures of error reduction as criteria for the effectiveness of their CRM and human factors training programs. Now that this, and other studies have begun to focus on specific error types which are associated with performance, these errors should be targeted and eradicated. Specific measures, by aircraft type, would need to be developed to make this recommendation feasible, which leads to the third recommendation.

More research needs to be done to identify error type by aircraft type, mission segment, and crew position. Dwindling training resources require efficiency. To better focus training time, manpower, and funds, it is imperative that we identify the appropriate problem areas. Much of this research can, and should be done by the crewmembers themselves. Many mid-career officer aviators are involved in advanced degree programs, and possess the required research skills to take on an error identification project in an area in which they are intimately familiar--namely their aircraft and crew position. Professional aviators must take the responsibility for our their own collective, as well as individual improvement. An appropriate forum for the dissemination of this data must be made available. Currently, the flying safety magazines offer the best opportunity for widest dissemination.

A Final Perspective

Due to the tremendous success of DESERT SHIELD and DESERT STORM, the aircraft may have ascended to the top of the list as the "weapon of choice" for future conflicts. Airpower's new motto of "global reach and global power" will undoubtedly gain even more favor with the development and deployment of new aircraft, and advanced precision guided munitions. Strategic and operational doctrine for these new weapons systems are being refined by some of the best airpower theorists in the world today. But at the tip of the tactical spear is a human, operating a complex machine in an ever changing environment, against a thinking and clever enemy. The *weapon system,* for all of its technical grandeur, is controlled by the imperfect hand (and mind) of man. As this study has shown, human error is often the limiting factor in combat operations. But this does not have to remain a static equation. Human factors training can focus on the specifics of error prevention. To realize the full benefit of improved technology in combat, it will require the same dedication of effort and resources to develop the human half (three-quarters?) of the weapon system as we put into developing the mechanized side.

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